Bay of Bengal Surface and Thermocline and the Arabian Sea

Arnold L. Gordon
Lamont-Doherty Earth Observatory of Columbia University
61 Route 9W
Palisades, NY 10964-8000
phone: (845) 365-8325; fax: (845) 365-8157; e-mail: agordon@ldeo.columbia.edu

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LONG-TERM GOALS

Investigate and quantify the oceanographic processes that exchange low salinity surface and upper thermocline water of the Bay of Bengal with the salty Arabian Sea and tropical Indian Ocean belt, including their seasonal and interannual variability and the impact on the regional structure of the thermohaline stratification within the two northern embayments of the Indian Ocean.

OBJECTIVES

Two northern Indian Ocean embayments, the Arabian Sea and the Bay of Bengal, are so close yet so different, one relatively fresh the other salty. The input of freshwater into BoB must be balanced, in quasi-stationary steady state, by export of freshwater to the Arabian Sea to offset its net evaporation. Complicating the study of the inter-bay exchange is the vigorous mesoscale field. The program objectives are: 1. Relating the Bay of Bengal mesoscale features, including an observed Intrathermocline eddy, to regional climatology e.g. where do the eddies come from? 2. Investigating advective pathways, and the role of isopycnal mixing, exchanging upper ocean water between the low salinity Bay of Bengal water and the saline water of the Arabian Sea; 3. Quantifying the connectivity of Bay of Bengal and to the Arabian Sea to the tropical Indian Ocean water, including the Indonesian Throughflow.

APPROACH

In situ observational data collected as part of ASIRI and NASCar DRI and satellite derived data (SST, SSH, SSS, Ocean Color), are related to the regional climatology captured by the archival data and 2003-2015 Argo climatology. Additionally, the oceanography of the northern Indian Ocean embayments and tropical Indian Ocean are related to the larger scale ocean and climate system, e.g. monsoon, ENSO and the Indonesian Throughflow.

WORK COMPLETED

The Low Latitude Indian to Western Pacific region displays a surprising large range of temperature and salinity, both regionally and within a complex mesoscale field, representing a balance between atmospheric forcing and ocean exchange processes. The system is strongly interactive with the Asian monsoon and with ENSO, and plays a key role in setting the larger scale ocean/climate condition.

Figure 1 portrays the regional sea surface ocean components and complex patterns.

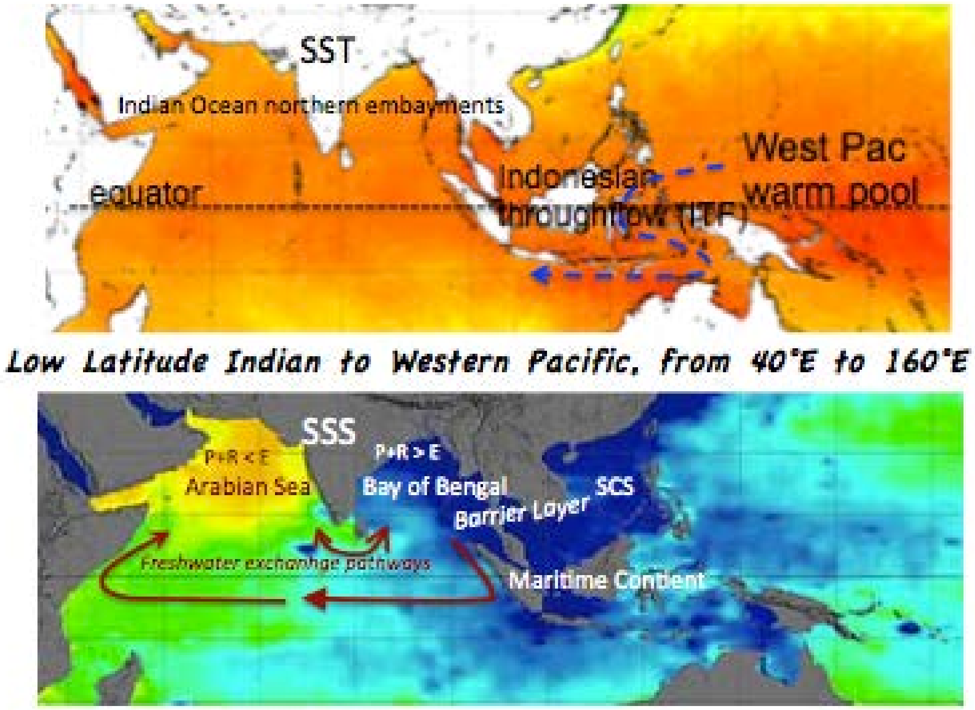


Figure 1. Tropical Indian Ocean and western Pacific. A region of ocean complexity amidst the monsoon and ENSO climate.

The Bay of Bengal (BoB), with its relatively fresh surface layer, responding to monsoonal forcing, is composed of complex field of mesoscale (and sub mesoscale) features superimposed on a regional pattern. Within the limited region covered by the ASIRI 2013 cruises, the full range of thermohaline stratification across the Bay of Bengal as resolved by the 2003-2015 Argo array is observed. The source of the waters within the observed mesoscale features have been identified within the Argo 2003-2015 climatology; the source waters are generally found to the east of the eddies. Active along shore advective flow is found along the eastern and western margins of the Bay of Bengal, but the tidally active Andaman Sea of the eastern margin provides a unique water mass signature.

Figure 2 shows that the surface water temperature/salinity (T/S) scatter within the Bay of Bengal is surprisingly complex. Energetic mesoscale features stir the varied surface water types.

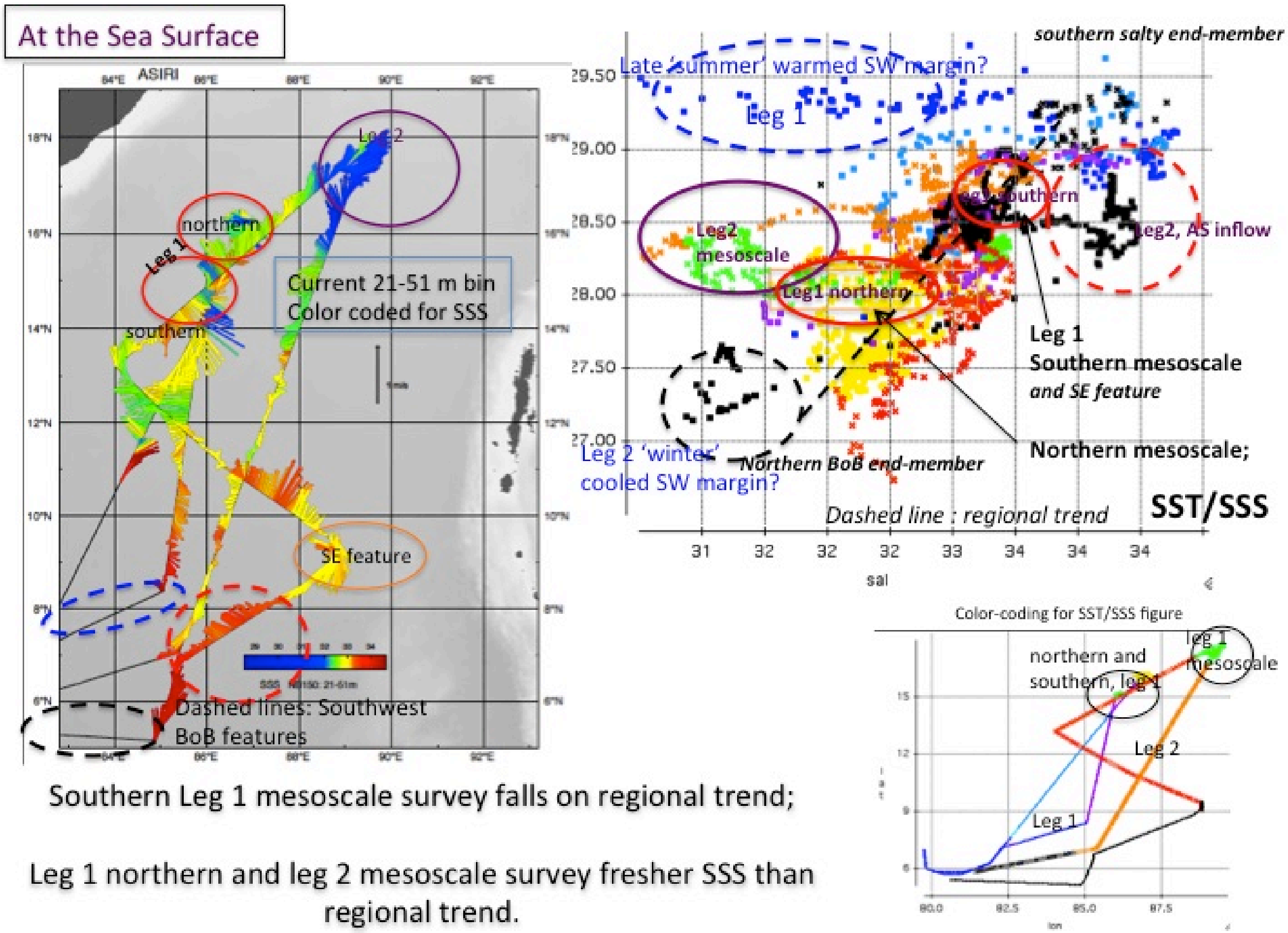


Figure 2: The surface water T/S scatter within the Bay of Bengal is surprisingly complex, as energetic mesoscale features stir the varied surface water types. The mesoscale ocean processes shape the SST and air-sea exchange.

Figure 3 shows how the ASIRI cruise data of 2013 is related to the Argo climatology displayed in 2°x2° lat/long boxes.

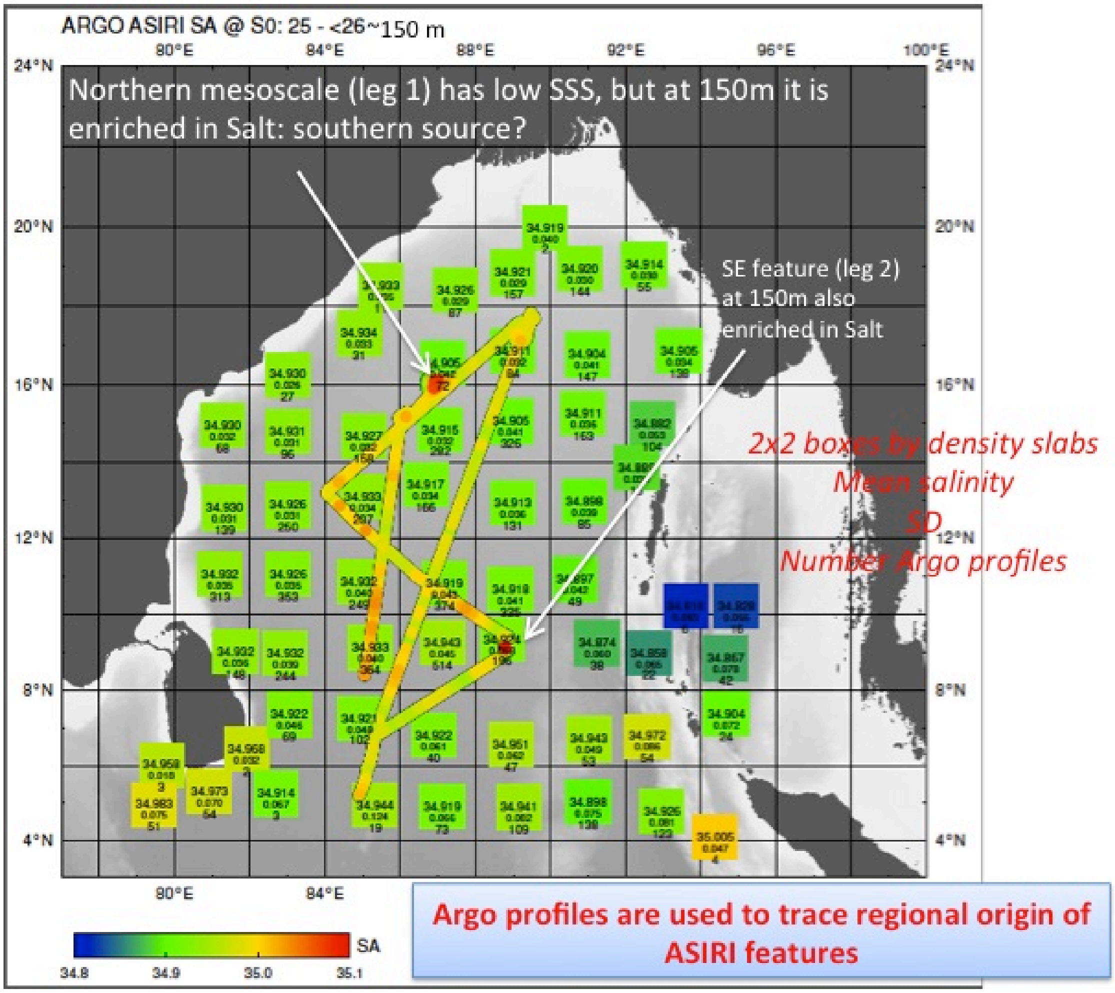


Figure 3: Composite of Argo data (2003-2014) within 2° by 2° latitude/longitude boxes in density (σ) layers (shown here is the 25-26 density slab). The color-coding is the salinity (scale in lower left); within each box is the salinity value, the standard deviation and the number of Argo data points, respectively. The same salinity color scale is added to the CTD stations of the 2 ASIRI 2013 cruises. The figure shows the high salinity (red dots) at two CTD site, which likely are derived from inflow from the Arabian Sea.

During leg 2 of the 2013 ASIRI cruises in the Bay of Bengal the underway CTD observed an Intrathermocline eddy (ITE) shown in Figure 4. The ITE I position shown on map, upper left. The isopycnal on the salinity field is lower left. The upper right shows the T/S of the ITE core and the T/S of the waters surrounding the ITE, in which a significant velocity field is associated with the displaced isopycnals, with limited sea surface expression. The geostrophic current relative to 200 m, marking the base of the ITE shows a maximum current of ~0.25 m/sec at 70-80 meters depth. The surface current is about 50% of the subsurface v-max. The Argo profiles from January 2013 matching to the T/S stratification are found to the northeast of ASIRI ITE. Figure 5 shows the positions of the matching Argo profile and ASIRI CTD stations. This does not imply that Argo observed the same ITE as observed ASIRI leg 2, but rather ITE may be common in the northeast monsoon. It is proposed that the ITE traveled westward from the eastern Bay of Bengal, a common trait of other mesoscale features.

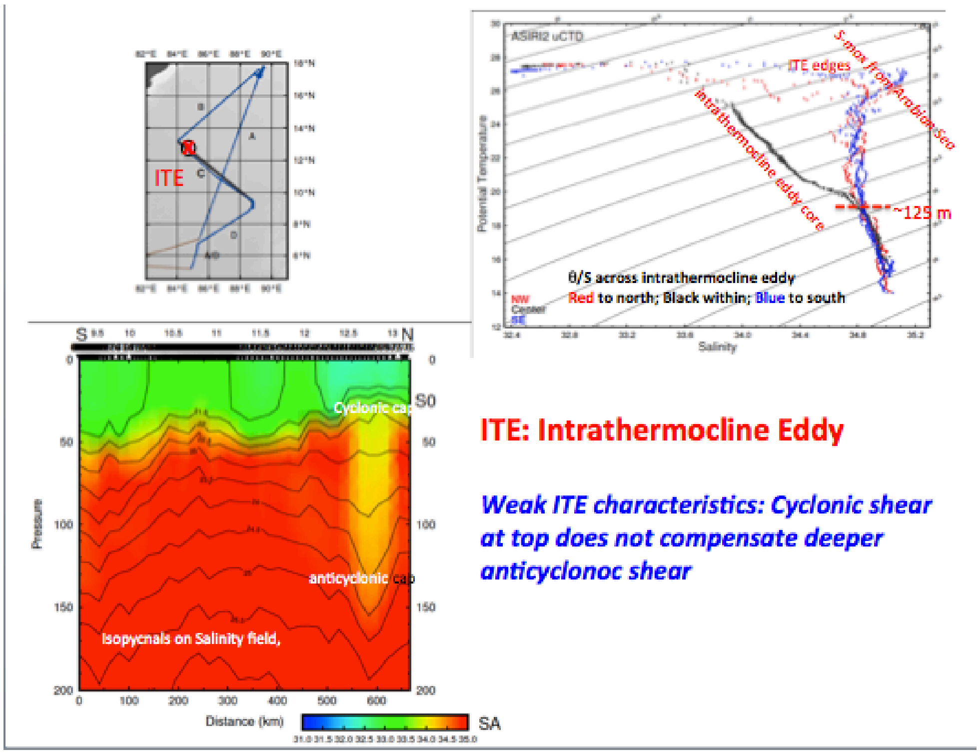


Figure 4 Intrathermocline eddy position shown on map, upper left. The isopycnal on the salinity field is lower left. The upper right shows the T/S of the ITE core and the T/S of the waters surrounding the ITE

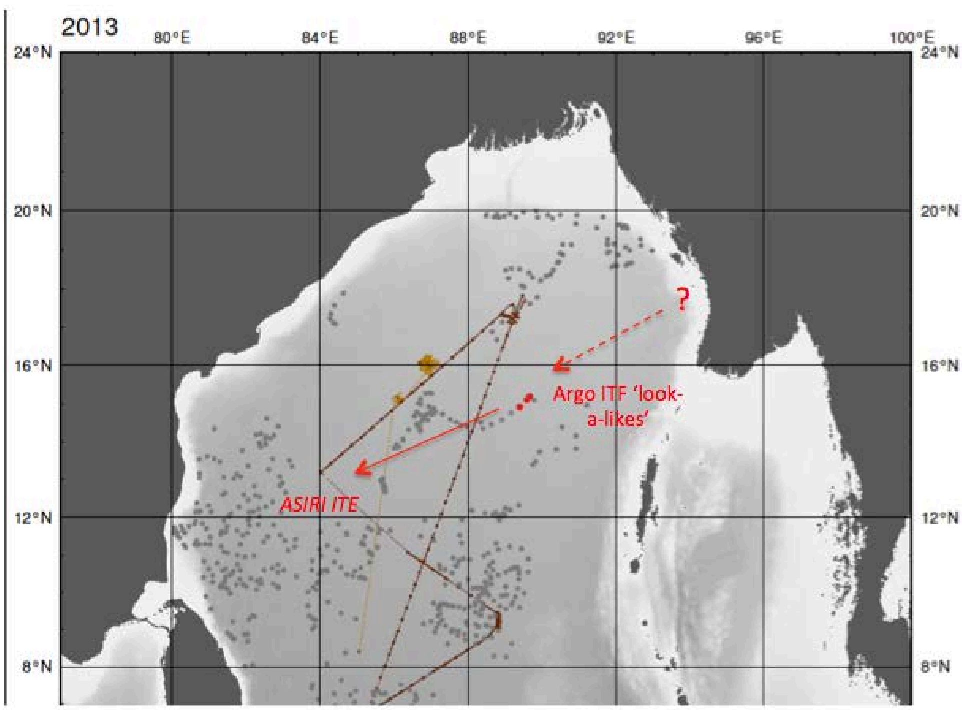
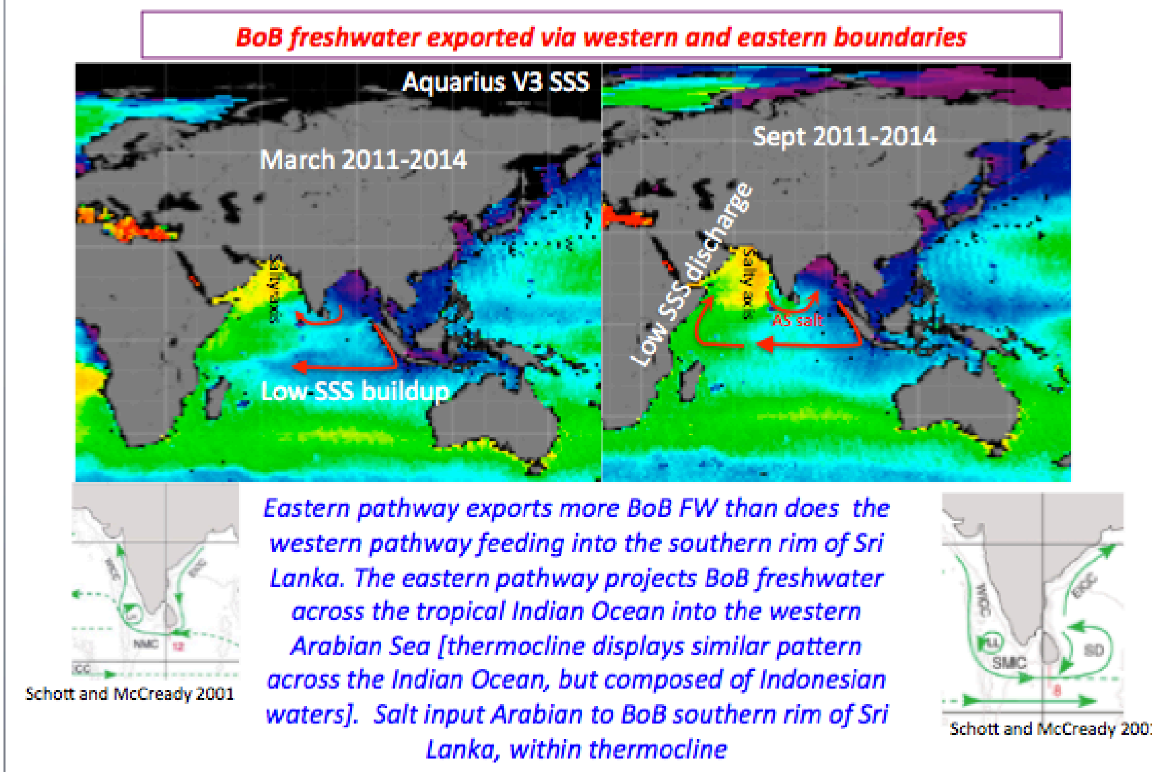


Figure 5: Map showing the ITE and Argo profiles best matching the ITE. Based on the Argo climatology, it is proposed that the water of the ITE core is derived from the eastern Bay of Bengal.

Bay of Bengal (BoB) and Arabian Sea (AS) exchange their sharply contrasting waters by way of the monsoon govern flow around the southern rim of Sri Lanka and freshwater export along the BoB eastern boundary that is then injected into the westward flow crossing the tropical Indian Ocean, some of which reaches into AS. Figure 5 shows likely BoB and AS exchange pathways shown by the red arrows. The regional flow patterns around Sri Lanka is shown by the two smaller inserts from Schott and McCready (2001).



There are two pathways to export the BoB freshwater within the surface later: **indirect**: along the BoB eastern boundary spreading southward along the western limit of the maritime continent, then turning westward within the tropical latitudes reaching the western margins of the Indian Ocean; **indirect**: by a path along the western limb of BoB directly into the Arabian Sea around the southern rim of Sri Lanka. I hypothesis that the eastern pathway exports more BoB FW than does the Sri Lanka pathway, though both are important in achieving quasi-stationary steady state. The BoB freshwater reaching into the western Indian Ocean eventually (seasonally) spreads into the western Arabian Sea. Salt input from the AS to BoB is along the southern rim of Sri Lanka, within BoB thermocline, mostly in the 50-150 m interval.

IMPACT/APPLICATION

Understanding the upper ocean processes and exchange pathways linking the two contrasting northern embayments of the Indian Ocean provides insight to the forces governing the large spatial and temporal range of the regional thermohaline stratification and mesoscale features.

HONORS/AWARDS/PRIZES

Houghton Lecturer, Massachusetts Institute of Technology. Spring semester 2015